Data Communication and Net-Centric Computing

COSC 1111/2061/1110

Lecture 10

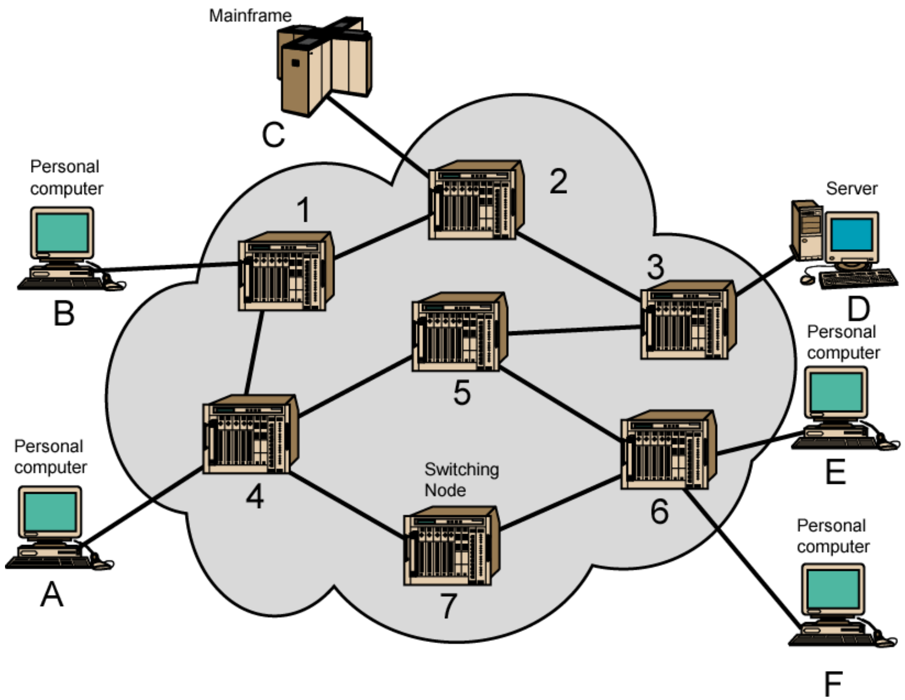
Wide Area Networks, Packet and Circuit Switching, ATMs

Lecture Overview

- During this lecture, we will understand
  - Wide area networks
  - circuit switching concepts
  - Packet switching concepts
  - Introduce ATMs

- Recommended reading
  - Chapters 10 and 11 (Stallings)

Simple Switched Network



- ❖ Station
  - End devices that communicates with each other
  - Connected to nodes
- ❖ Node
  - Switching device connected to other nodes
- ❖ Network
  - Set of nodes takes part in connection

❖A collection of nodes and connections is a communication network

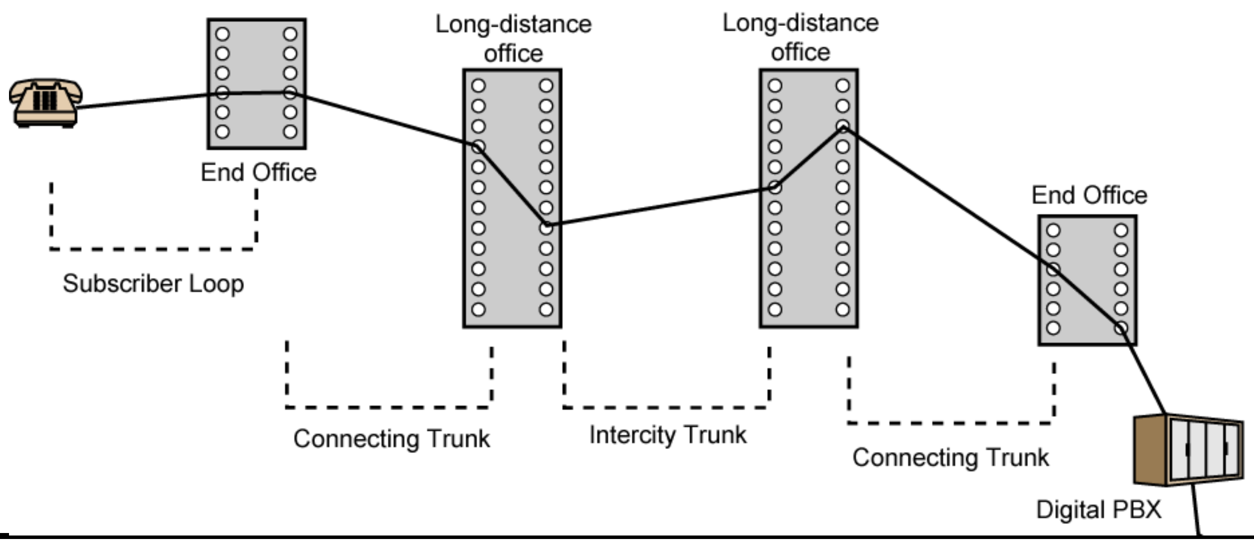
❖Data routed by being switched from node to node

❖Two different switching technologies

- Circuit switching
- Packet switching

Circuit Switching

- Dedicated communication path between two stations
- Three phases
  - Establish
  - Transfer
  - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing

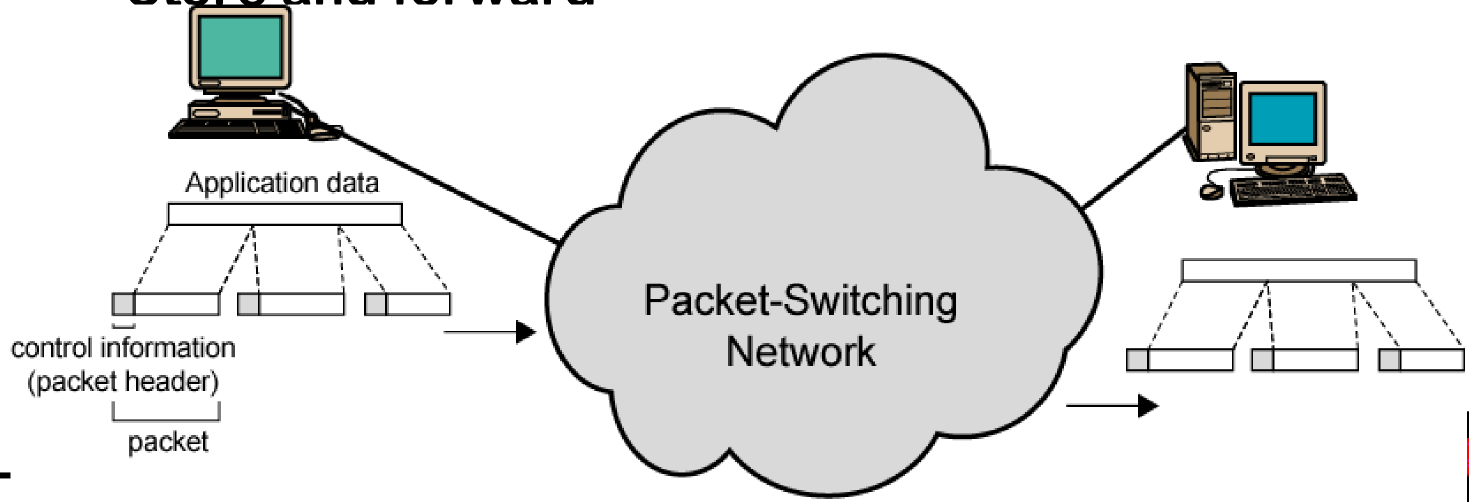


Characteristics of Circuit Switching

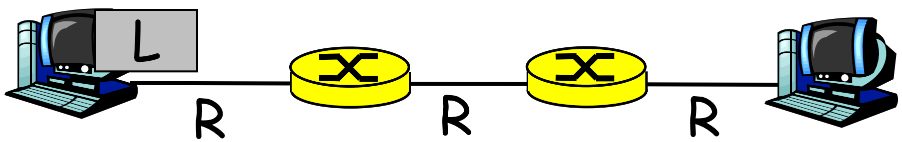
- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Circuit switching designed for voice
  - Resources dedicated to a particular call
  - Much of the time a data connection is idle
- Blocking- A network is unable to connect stations because all paths are in use
  - Used on voice systems. Short duration calls
- Non-blocking- Permits all stations to connect (in pairs) at once
  - Used for some data connections

Basic Operation of Packet Switching

- Data transmitted in small packets
  - Longer messages split into series of packets
  - Each packet contains a portion of user data plus some control info
- Control info
  - Routing (addressing) info
- Packets are received, stored briefly (buffered) and passed on to the next node
  - Store and forward



Packet-switching: store-and-forward



- Takes L/R seconds to transmit (push out) packet of L bits on to link or R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R

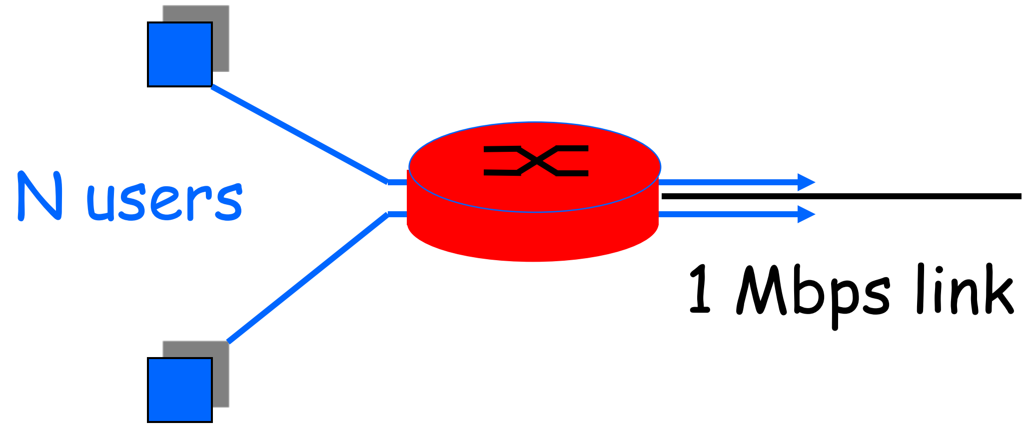
Example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- delay = 15 sec

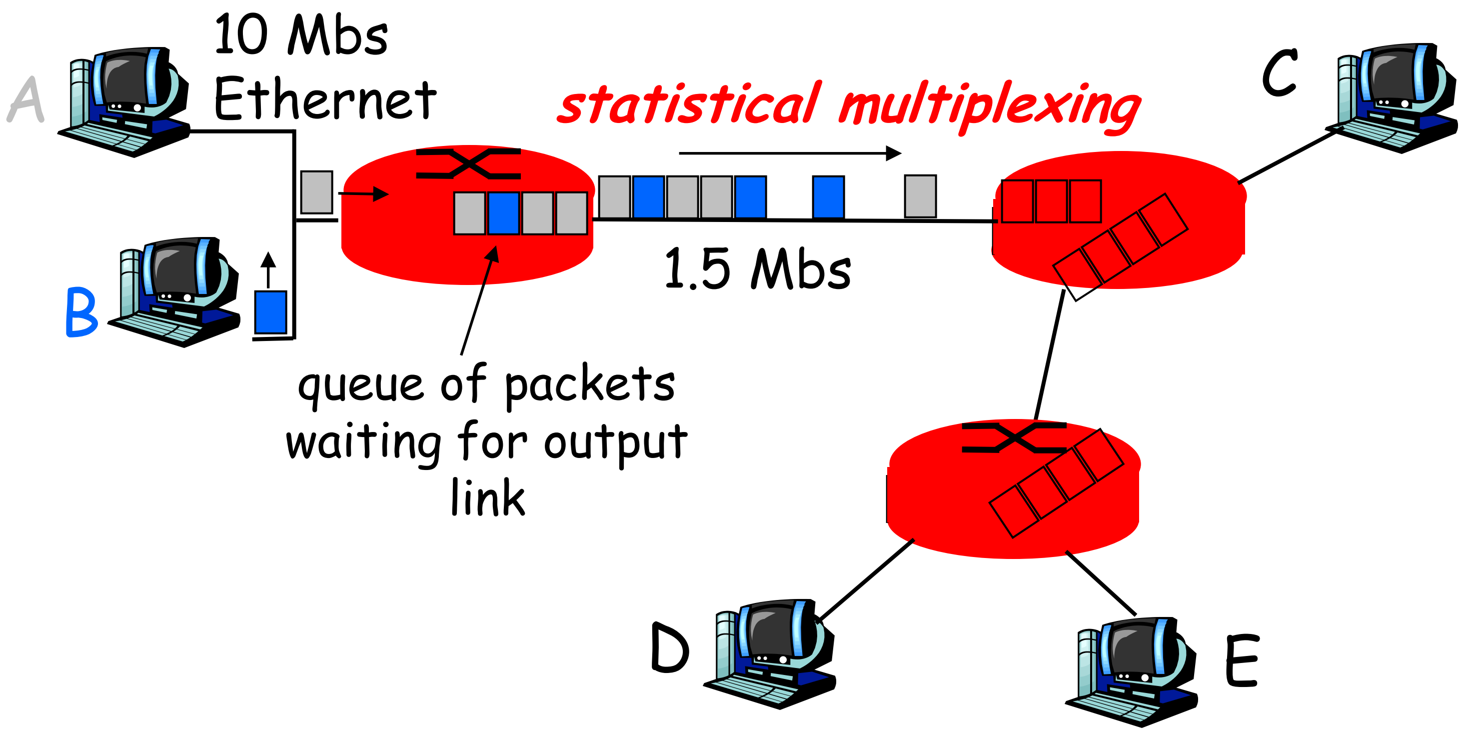
Packet switching versus circuit switching

Packet switching allows more users to use network!

- 1 Mbit link
- each user:
  - 100 kbps when "active"
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - Lot more than 10
  - How? Statisical Mux.



Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern → *statistical multiplexing*.

In TDM each host gets same slot in revolving TDM frame.

Advantages

- Line efficiency
  - Single node to node link can be shared by many packets over time
  - Packets queued and transmitted as fast as possible
- Data rate conversion
  - Each station connects to the local node at its own speed
  - Nodes buffer data if required to equalize rates
- Packets are accepted even when network is busy
  - Delivery may slow down
- Priorities can be used

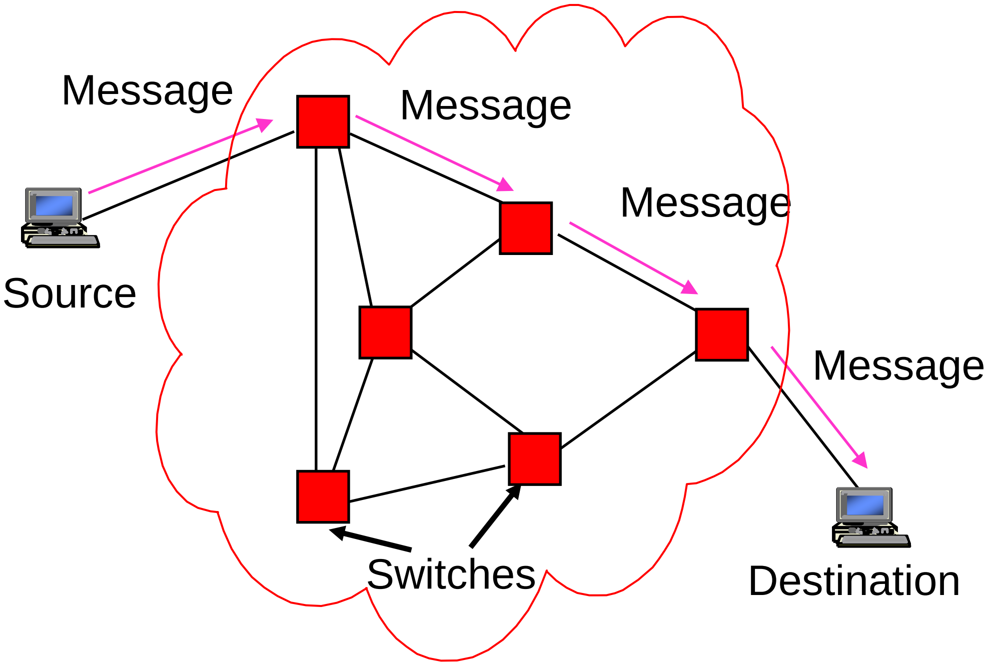
End-to-End Packet Network

- Packet networks very different than telephone networks
- Individual packet streams are highly bursty
  - Statistical multiplexing is used to concentrate streams
- User demand can undergo dramatic change
  - Peer-to-peer applications stimulated huge growth in traffic volumes
- Internet structure highly decentralized
  - Paths traversed by packets can go through many networks controlled by different organizations
  - No single entity responsible for end-to-end service

Packet Switching Techniques

- Origin in message switching
- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets handled in two ways
  - Datagram
  - Virtual circuit

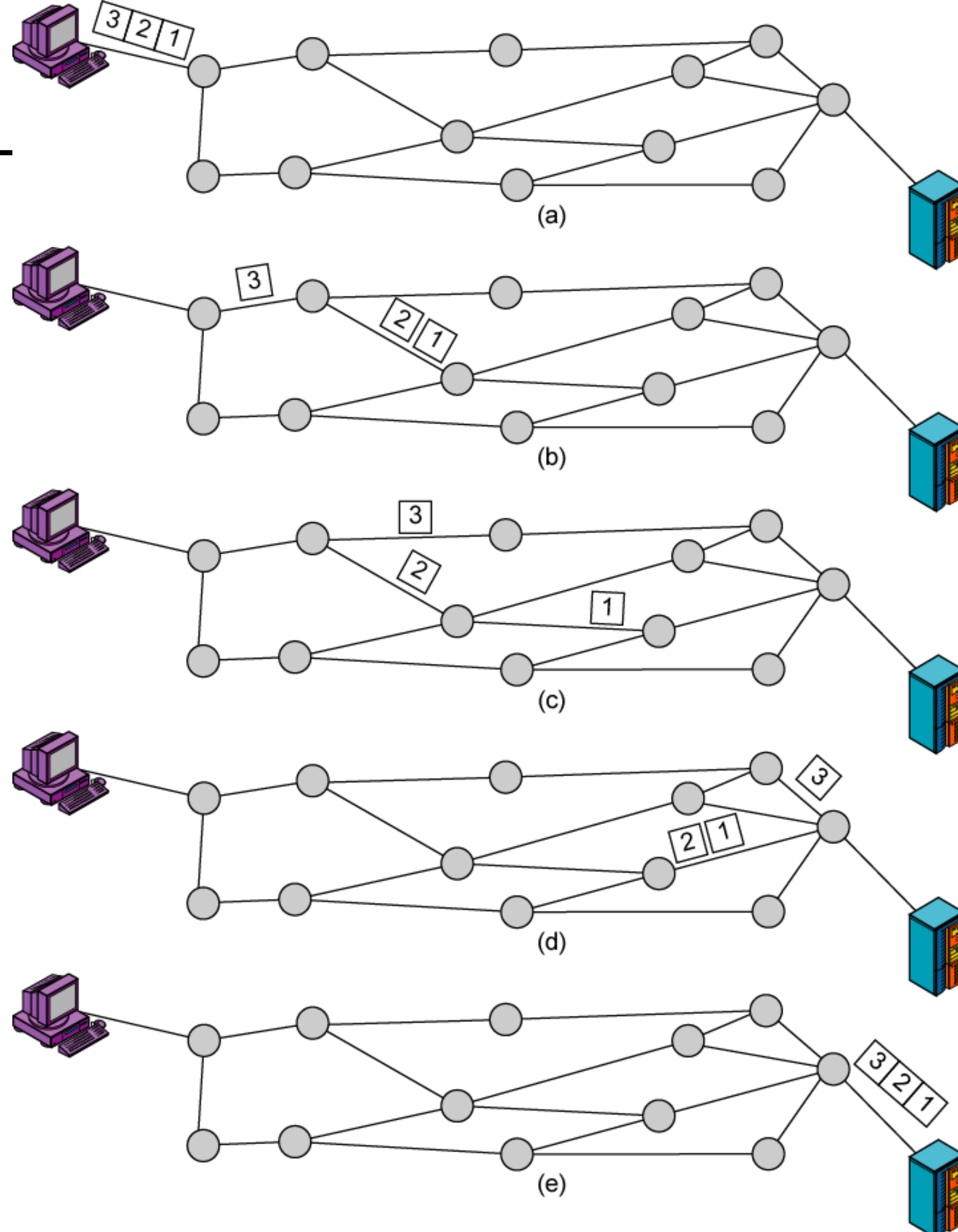
Message Switching



- Message switching invented for telegraphy
- Entire messages multiplexed onto shared lines, stored & forwarded
- Headers for source & destination addresses
- Routing at message switches
- Connectionless

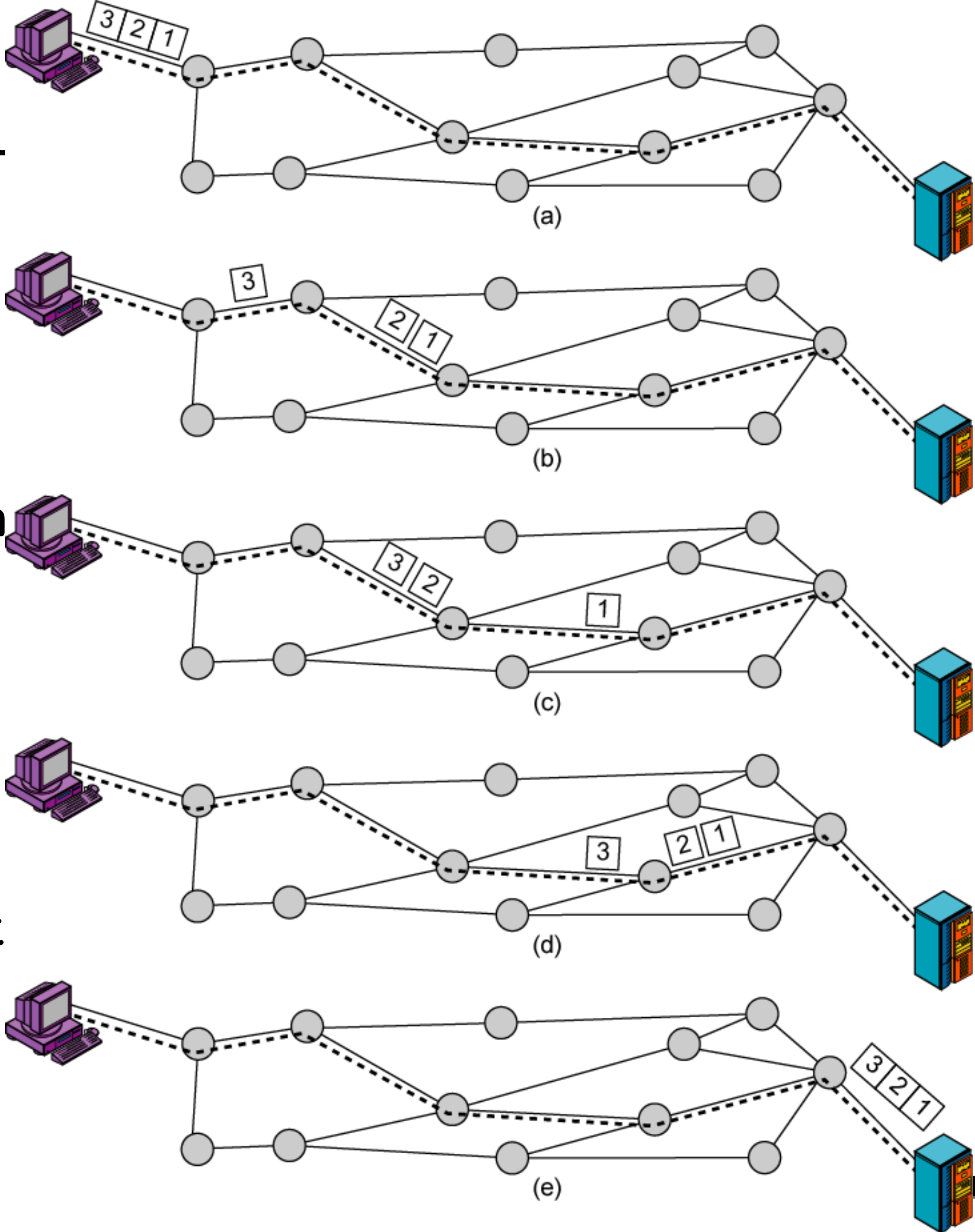
Datagram

- Each packet treated independently
- Source & destination addresses in packet header
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets



Virtual Circuit

- Preplanned route
- All packets for a connection follow the same path
- Call request and call accept packets establish connection (handshake)
- Each packet contains a virtual circuit identifier instead of destination address
- No routing decisions required for each packet
- Clear request to drop circuit
- Not a dedicated path

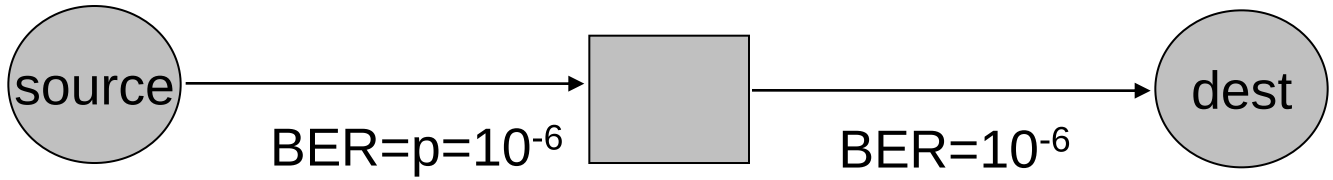


Virtual Circuits v Datagram

- Virtual circuits
  - Network can provide sequencing and error control
  - Packets are forwarded more quickly
    - No routing decisions to make
  - Less reliable
    - Loss of a node looses all circuits through that node
- Datagram
  - No call setup phase
    - Better if few packets
  - More flexible
    - Routing can be used to avoid congested parts of the network

Long Messages vs. Packets

1 Mbit message



How many bits need to be transmitted to deliver message?

- **Approach 1: send 1 Mbit message**
- **Probability message arrives correctly**

$$P_c = (1-10^{-6})^{10^6} \approx e^{-10^6 10^{-6}} = e^{-1} \approx 1/3$$

- **On average it takes about 3 transmissions/hop**
- **Total # bits transmitted ≈ 6 Mbits**

- **Approach 2: send 10 100-kbit packets**
- **Probability packet arrives correctly**

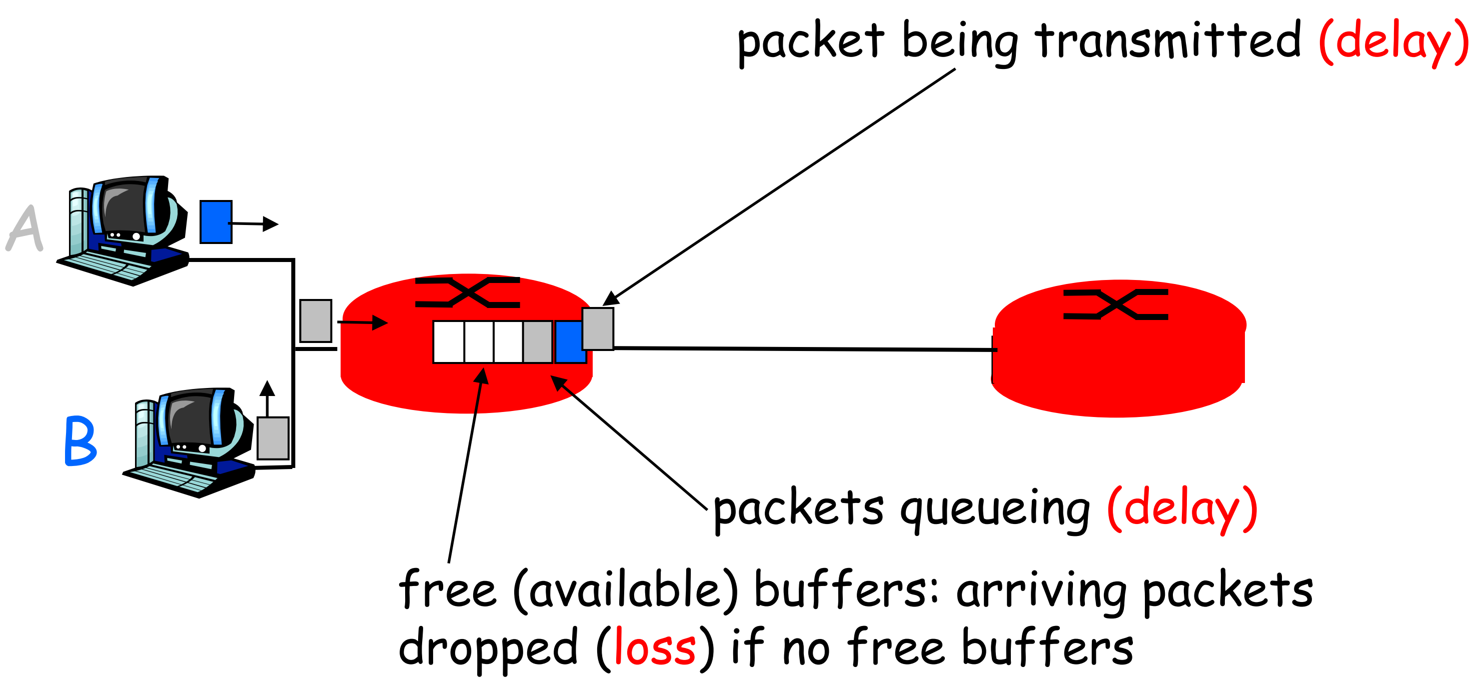
$$P'_c = (1-10^{-6})^{10^5} \approx e^{-10^5 10^{-6}} = e^{-0.1} \approx 0.9$$

- **On average it takes about 1.1 transmissions/hop**
- **Total # bits transmitted ≈ 2.2 Mbits**

How do loss and delay occur?

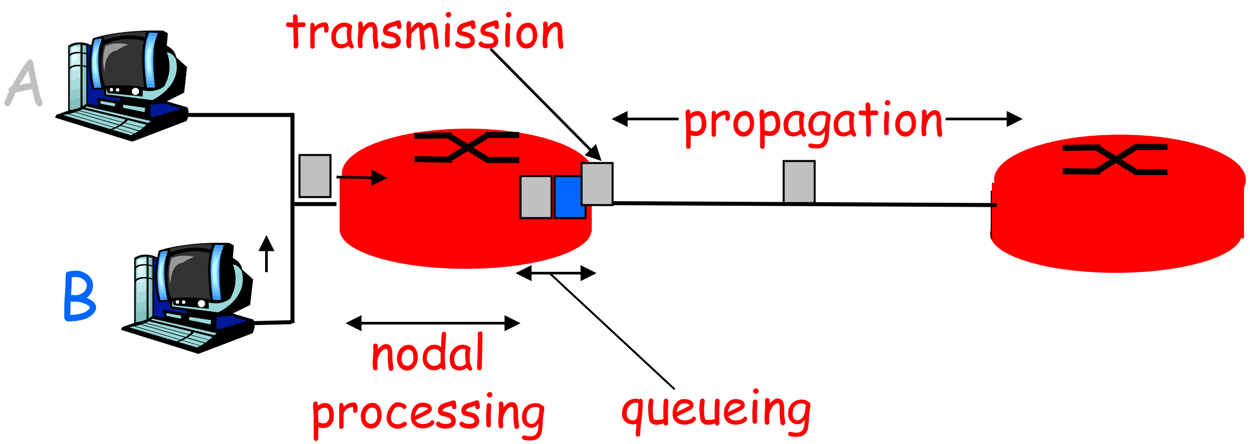
packets *queue* in router buffers

- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay

- 1. nodal processing:
  - check bit errors
  - determine output link
- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router



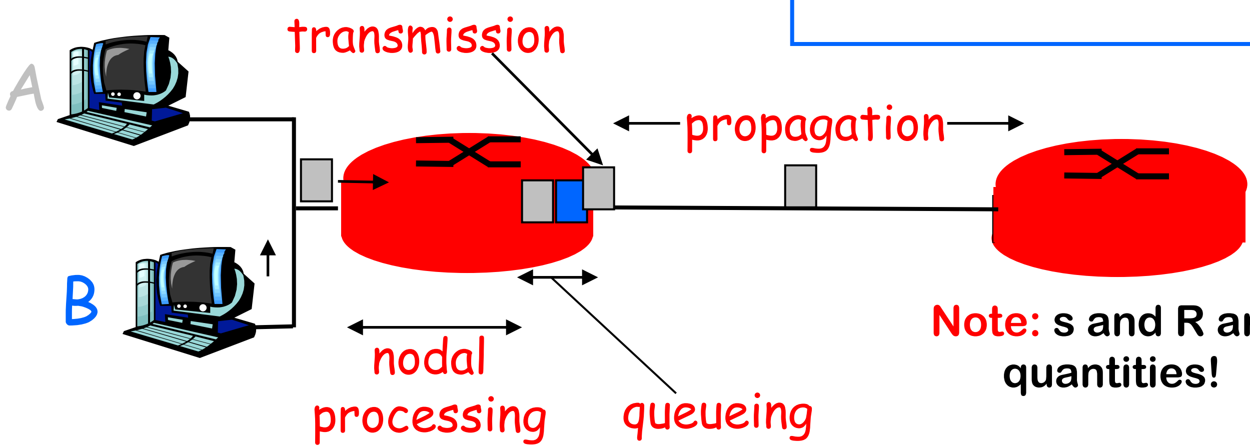
Delay in packet-switched networks

3. Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

4. Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~$2x10^8$ m/sec)
- propagation delay = d/s



Note: s and R are *very* different quantities!

Nodal delay

$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

- d_{proc} = processing delay
  - typically a few microsecs or less
- d_{queue} = queuing delay
  - depends on congestion
- d_{trans} = transmission delay
  - = L/R, significant for low-speed links
- d_{prop} = propagation delay
  - a few microsecs to hundreds of msecs

“Real” Internet delays and routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

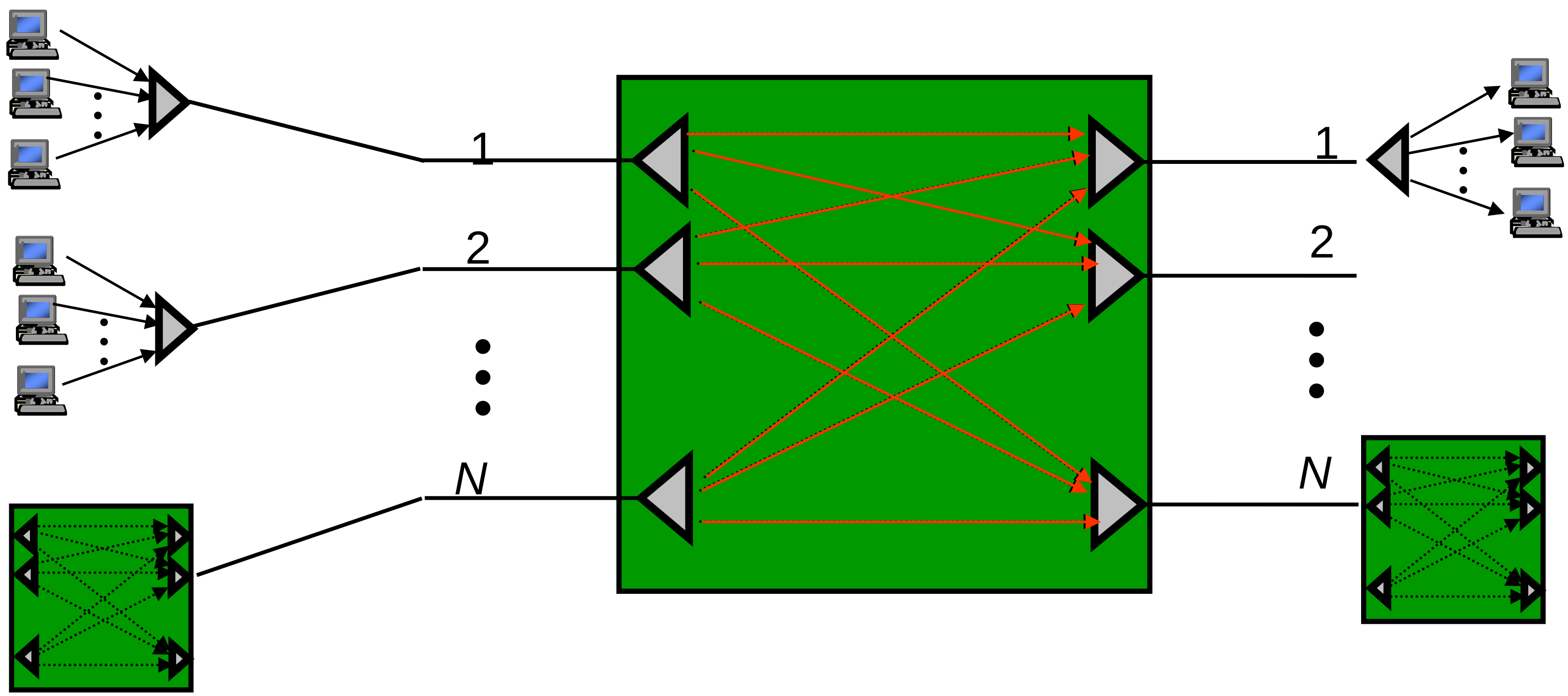
Three delay measements from gaia.cs.umass.edu to cs-gw.cs.umass.edu

1 cs-gw (128.119.240.254) 1 ms 1 ms 2 ms
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms
3 cht-vbns.gw.umass.edu (128.119.3.130) 6 ms 5 ms 5 ms
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms
5 jn1-so7-0-0-0.wae.vbns.net (204.147.136.136) 21 ms 18 ms 18 ms
6 abilene-vbns.abilene.ucaid.edu (198.32.11.9) 22 ms 18 ms 22 ms
7 nycm-wash.abilene.ucaid.edu (198.32.8.46) 22 ms 22 ms 22 ms
8 62.40.103.253 (62.40.103.253) 104 ms 109 ms 106 ms
9 de2-1.de1.de.geant.net (62.40.96.129) 109 ms 102 ms 104 ms
10 de.fr1.fr.geant.net (62.40.96.50) 113 ms 121 ms 114 ms
11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms
12 nio-n2.cssi.renater.fr (193.51.206.13) 111 ms 114 ms 116 ms
13 nice.cssi.renater.fr (195.220.98.102) 123 ms 125 ms 124 ms
14 r3t2-nice.cssi.renater.fr (195.220.98.110) 126 ms 126 ms 124 ms
15 eurecom-valbonne.r3t2.ft.net (193.48.50.54) 135 ms 128 ms 133 ms
16 194.214.211.25 (194.214.211.25) 126 ms 128 ms 126 ms
17 * * *
18 * * *
19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms

trans-oceanic link

* means no reponse (probe lost, router not replying)

Packet Switch: Intersection where Traffic Flows Meet



- Inputs contain multiplexed flows from access muxs & other packet switches
- Flows demultiplexed at input, routed and/or forwarded to output ports
- Packets buffered, prioritized, and multiplexed on output lines

Asynchronous Tranfer Mode (ATM)

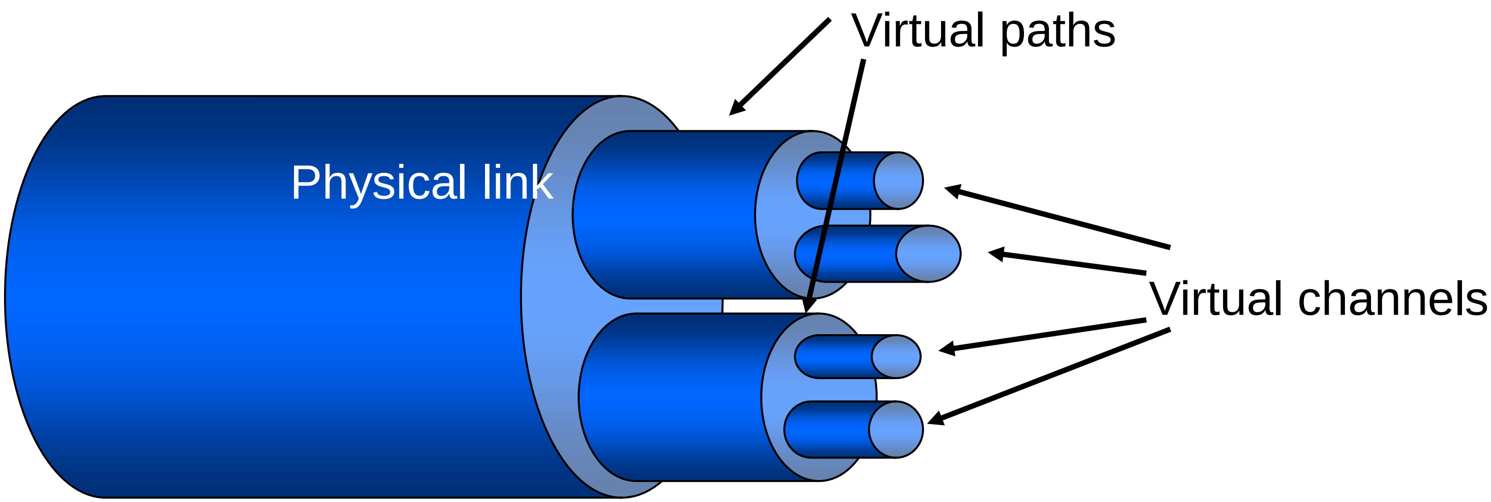
- Packet multiplexing and switching
  - Fixed-length packets: “cells”
  - Connection-oriented
  - Rich Quality of Service support
- Conceived as end-to-end
  - Supporting wide range of services
    - Real time voice and video
    - Circuit emulation for digital transport
    - Data traffic with bandwidth guarantees
- Similarities between ATM and packet switching
  - Transfer of data in discrete chunks
  - Multiple logical connections over single physical interface
- Minimal error and flow control
  - Reduced overhead
- Data rates (physical layer) 25.6Mbps to 622.08Mbps

ATM Cells

- Fixed size
- 5 octet header
- 48 octet information field
- Small cells reduce queuing delay for high priority cells
- Small cells can be switched more efficiently
- Easier to implement switching of small cells in hardware

ATM Virtual Connections

- **VC transport:** cells carried on VC from source to dest
- Multiple VCs can be bundled within a VP
- **Permanent VCs (PVCs)**
  - long lasting connections
  - typically: "permanent" route between to IP routers
- **Switched VCs (SVC):**
  - dynamically set up on per-call basis



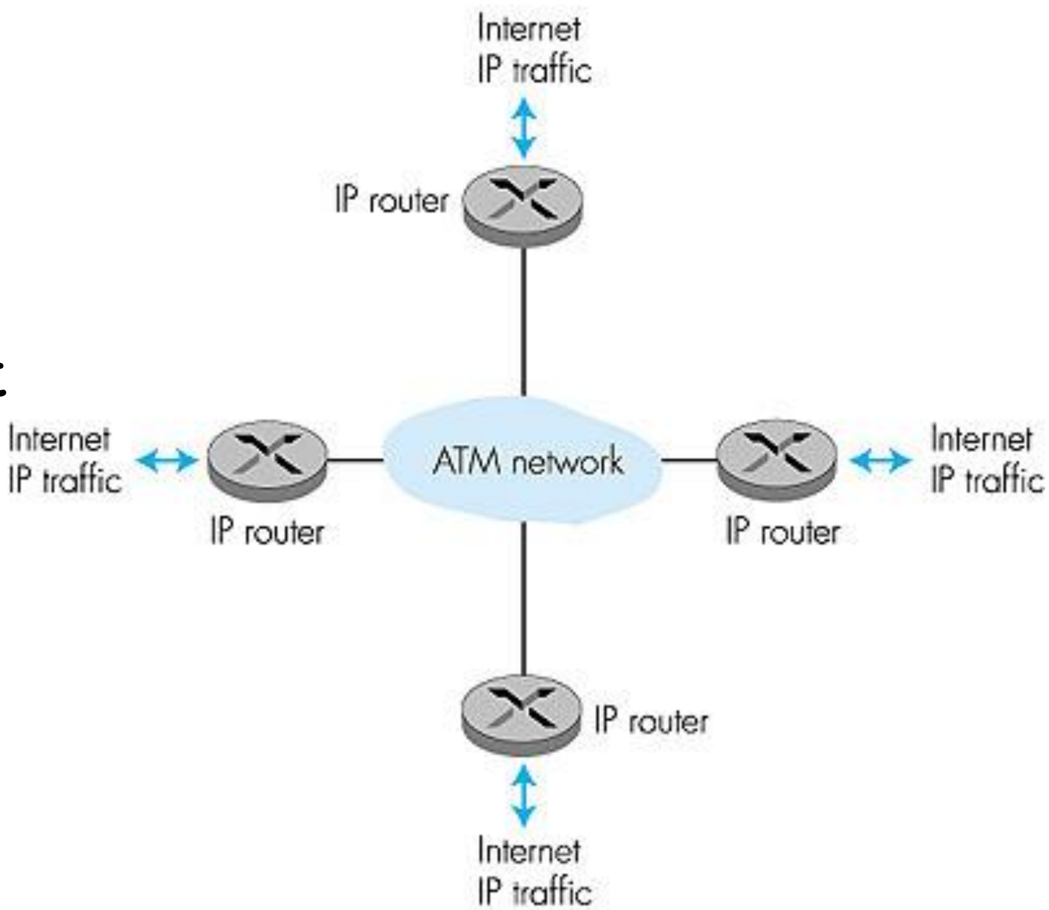
ATM: network or link layer?

Vision: end-to-end transport: "ATM from desktop to desktop"

- ATM *is* a network technology

Reality: used to connect IP backbone routers

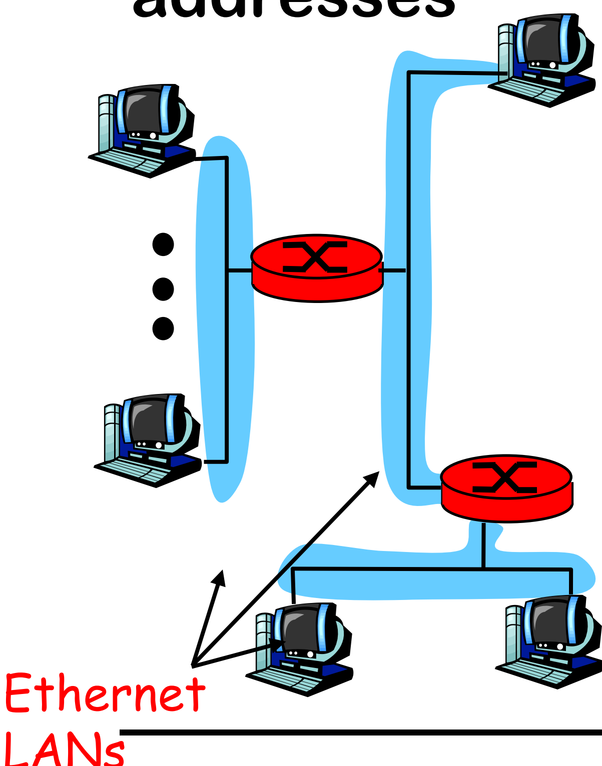
- "IP over ATM"
- ATM as switched link layer, connecting IP routers



IP-Over-ATM

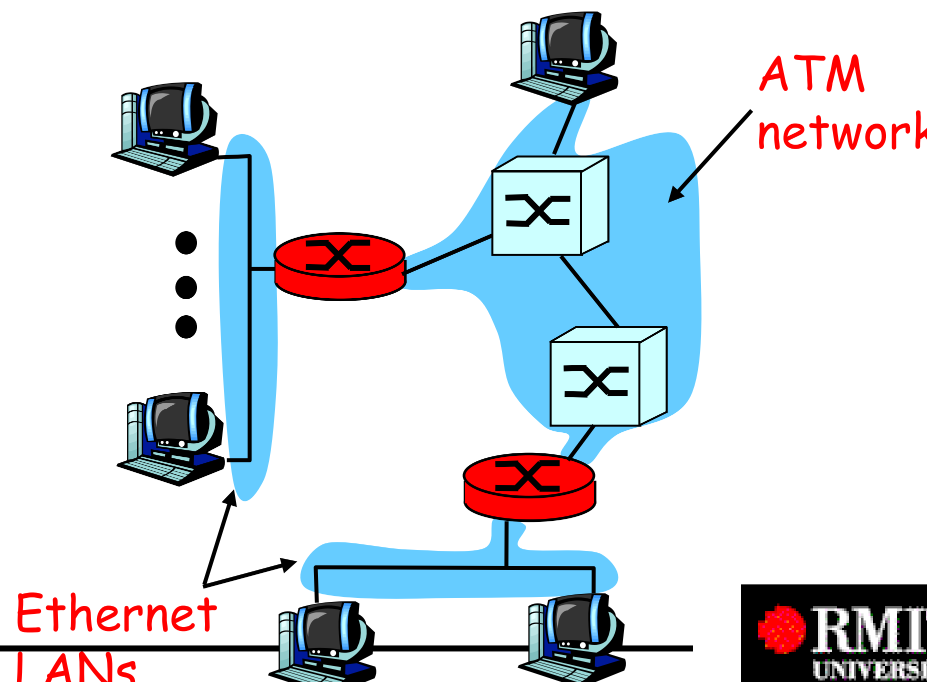
Classic IP only

- 3 "networks" (e.g., LAN segments)
- MAC (802.3) and IP addresses



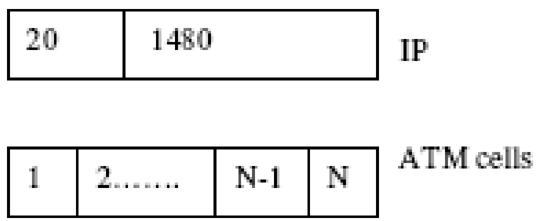
IP over ATM

- replace "network" (e.g., LAN segment) with ATM network
- ATM addresses, IP addresses



IP over ATM –an example

An IP packet consists of 20 bytes of header and 1480 bytes of payload. Now suppose that the packet is mapped into ATM cells that have 5 bytes of header and 48 bytes of payload. How much of the resulting cell stream is header overhead?



1500 bytes (IP packet) are divided into N cells where each cell is 48 bytes (ATM)
N = 1500 / 48 = 31.25 = 32 ATM cells

Each ATM cell has 5 bytes of header. Hence total over head = 32 * 5 (ATM cells) + 20 (from IP header)
= 180 bytes

$$\text{Header overhead} = \frac{\text{Total overhead bytes}}{\text{Total data}} = \frac{180}{1480 + 180}$$

180 / 1660 = 10.84 %

Last Words on ATM

- ATM initially touted as more scalable than packet switching
- ATM envisioned speeds of 150-600 Mbps
- ATM lost appeal with the advent of High Speed Eth.
- Advances in optical transmission proved ATM to be the less scalable: @ 10 Gbps
  - Segmentation & reassembly of messages & streams into 48-byte cell payloads difficult & inefficient
  - Header must be processed every 53 bytes vs. 500 bytes on average for packets
  - Delay due to 1250 byte packet at 10 Gbps = 1 μsec; delay due to 53 byte cell @ 150 Mbps $\approx$ 3 μsec
- ATM path (PVC) setup is a hop-by-hop approach.

Summary

- In this lecture, we have understood:
  - Circuit switching concepts
  - Packet Switching concepts
  - ATM networks

Next Time

- We will know about
  - Transport protocols
  - TCP flow control
  - UDP
- Suggested Reading:
  - Chapters 20 (Stallings)